View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by Elsevier - Publisher Connector

Available online at www.sciencedirect.com
ScienceDirect
Energy Procedia 88 (2016) 928 – 934
Energy Procedia

CUE2015-Applied Energy Symposium and Summit 2015: Low carbon cities and urban energy systems

Comparative Research on the Transmission Form of the Electric Bus

Wenwei Wang[a, *], Rui Hou[b], Quanqing Yu[a], Cheng Lin[a]

[a]National Engineering Laboratory for Electric Vehicle, Bejing Institute of Technology, No.5 Zhongguncun South Street, Haidian District, Beijing, 100081, P.R.of China
[b] Dept. of Automotive Engineering, Tsinghua University,Zhongguncun North Street, Haidian District, Beijing, 100081, P.R.of China

Abstract

This paper takes the transmission form of pure electric bus as the research object, models the direct-drive transmission system and AMT (Automated mechanical transmission) system. The economic comparison of the energy consumption is built by MATLAB/Simulink, the simulation results on the china typical city bus cycle reveals that the necessity of AMT on the pure electric bus, furthermore, the optimization of the shift schedule of AMT can effectively reduce the energy consumption of pure electric bus.

© 2016 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of the organizing committee of CUE 2015

Keywords: AMT (Automated mechanical transmission), energy consumption, pure electric bus, economic shift schedule

1. Introduction

Pure electric bus refers to the electric vehicle which is entirely driven by power battery. The structure of the drive transmission system has many kinds of forms [1]. Each form has its advantages and disadvantages. The structure of the direct-drive vehicle is simple and the transmission efficiency is high,

* Corresponding author. Tel.: +86-13520087169
E-mail address: bitev@bit.edu.cn.

1876-6102 © 2016 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of the organizing committee of CUE 2015
doi:10.1016/j.egypro.2016.06.114

but the reliability is poor and the cost is high. AMT has the advantages of high transmission efficiency, small size and low cost, which is the ideal transmission form of various pure electric vehicle, However, comparing with AT (Automatic Transmission) and MT (Manual Transmission), AMT also has certain drawbacks, such as the shifting quality, the starting performance and so on. The economic shift schedule is closely related to the energy management strategy [2], so the simulation optimization objective is the lowest energy consumption. In this paper, the comparison of the economic performance of the direct-drive vehicle and the vehicle equipped with AMT are carried out by MATLAB/Simulink.

2. COMPARISON OF TRANSMISSION SYSTEM

2.1. Main parameters of E_REB Simulation parameters

In this paper, the main parameters of the vehicle are shown in Table1. In order to simulate the actual energy consumption of pure electric bus, the comparison is mainly according to the driving cycle which in the "Test method for energy consumption of GBT19754-2005 heavy-duty hybrid electric vehicle". The basic information about the unit driving cycle can be seen in Table 2. The comparison of the energy consumption is built by MATLAB/Simulink.

Table 1 The main parameters of the vehicle

Vehicle type	Direct drive	AMT(Traditional)	AMT(Intelligent)
Peak torque of motor(Nm)	2900	850	850
Peak speed of motor(rpm)	3000	4500	4500
Peak power of motor(kw)	180	150	150
Gear ratio	/	4.403/2.446/1.507	4.403/2.446/1.507
Shift schedule	/	Double parameters economic	Intelligent economic

Table 2 Basic information about the unit driving cycle

Information	value
Driving time (s)	1314
Driving distance(km)	2900
Average speed (km/h)	15.9
Maximum speed (km/h)	60
Maximum acceleration(m/s^2)	0.914

2.2. Direct-drive vehicle

Direct-drive vehicle's simulation model is shown in Figure 1. The output end of the motor is directly connected with the main reducer.

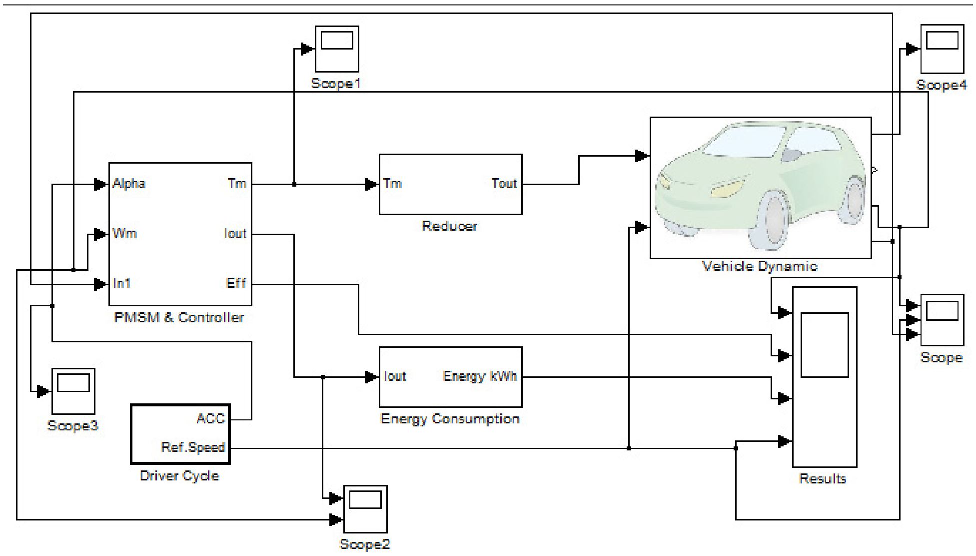

Figure. 1. Simulation model of direct-drive vehicle

The simulation results can be seen in Figure 2, the energy consumption when the vehicle drives 5.8 kilometers is 7.4185kWh, which means the energy consumption when the vehicle drives 100 kilometers is 127.905kWh.

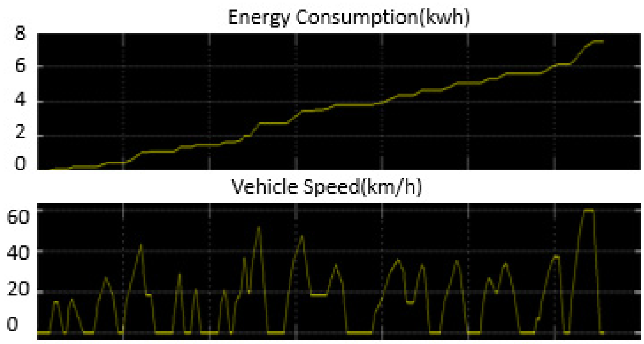

Figure. 2. Simulation results of direct-drive vehicle

2.3. AMT vehicle based on the double parameters economic shift schedule

Given the advantages of AMT over MT and AT, the shift schedule for an AMT-based electric vehicle have been studied by researchers [3]. In the process of automatic transmission, it can be seen as a close-loop system consisting of the driver, the vehicle and the driving environment. Shift schedule is based on the driver's intention, the vehicle's running state and road conditions and other factors, according to certain principles of optimal performance parameters of the vehicle, to determine the vehicle's best shift schedule. It directly affects the vehicle's power and economy. Control parameter is a parameter plays a decisive role in the conduct of the automatic transmission when the shift decision, according to these parameters, the current best positon is obtained by means of logical judgment. According to the different control parameters, the shift schedule can be divided into single parameter, double parameters and three parameters shift schedule. Shift schedule according to the optimization of the target is divided into the economic shift schedule and power shift schedule. In this paper, we use the double parameters economic shift schedule to control the shift.

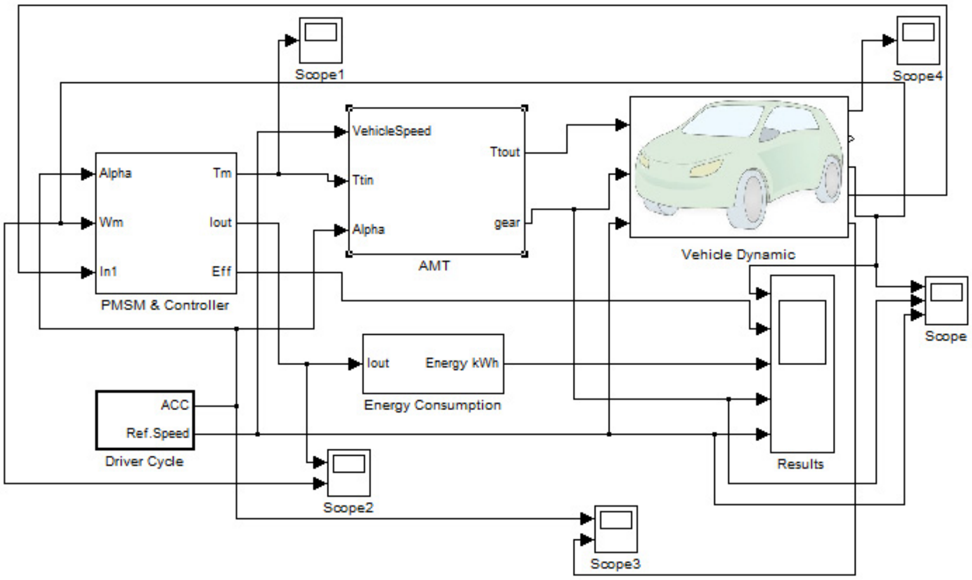

Figure. 3. Simulation model of AMT vehicle

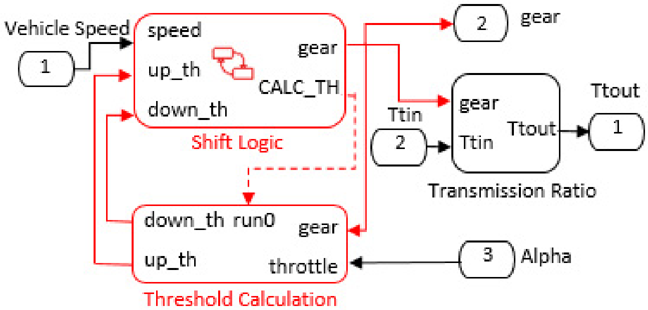

Figure. 4. AMT shift control logic

Simulation model of pure electric bus equipped with AMT can be seen in Figure 3, the shift control logic is shown in Figure 4, and the shift operation is carried out by using the speed and the accelerator pedal opening (u_a , α) - double parameters economic shift schedule, the double parameters economic shift curves are shown in Figure 5. The simulation results can be seen in Figure 6, the energy consumption when the vehicle drives 5.8 kilometers is 7.1208 kWh. which means the energy consumption when the vehicle drives 100 kilometers is 122.772kWh.

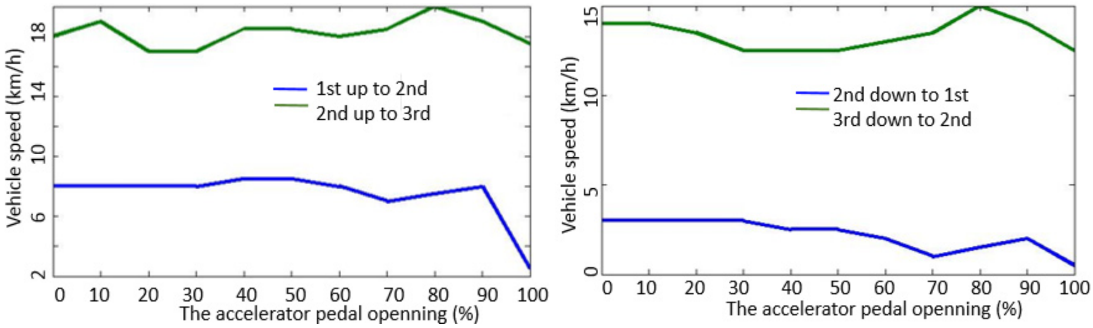

Figure .5. Double parameters economic shift curves

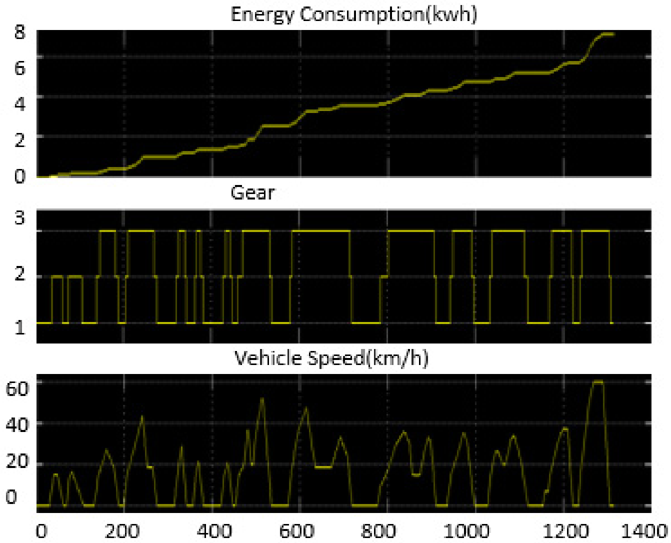

Figure. 6. Simulation results of AMT vehicle (double parameters)

2.4. AMT vehicle based on the shift schedule of cyclic operation mode

Taking into account the large number of idle parking and frequent acceleration and deceleration, in the formulation of the shift schedule, the simple double parameters cannot meet the requirements, then, we need to take full account of the driving cycles of the vehicle and design an intelligent shift schedule for pure electric bus. The simulation model of AMT vehicle which based on the intelligent economic shift schedule of cyclic operation mode is shown in figure7.

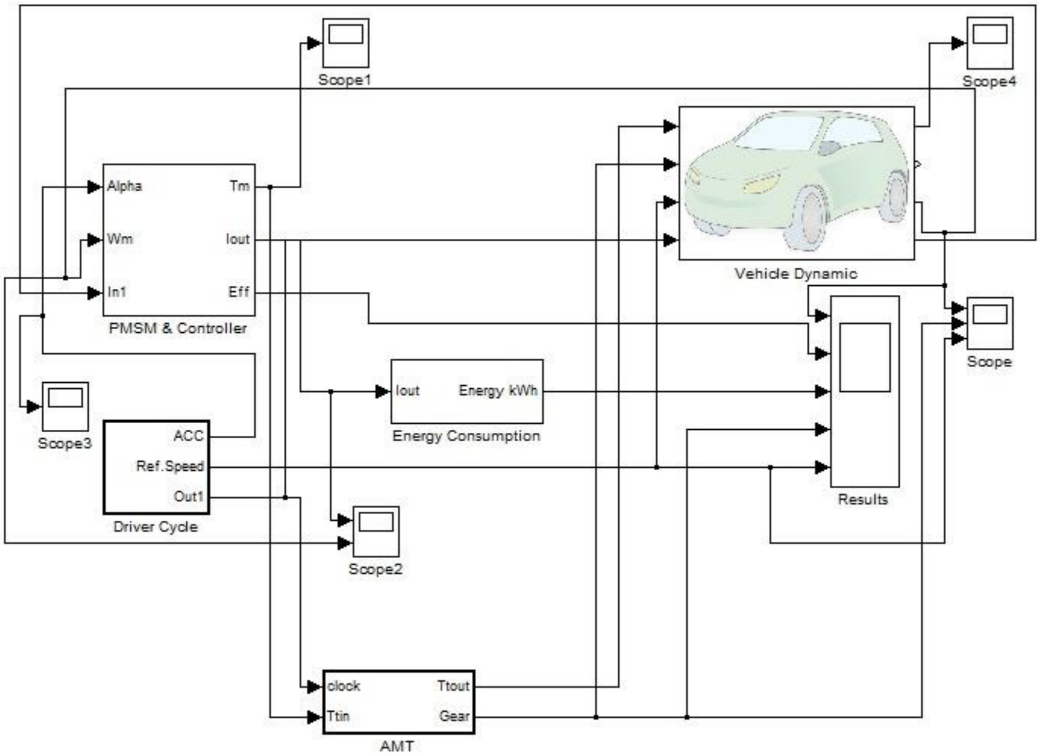

Figure. 7. Simulation model of AMT vehicle (Based on the intelligent economic shift schedule)

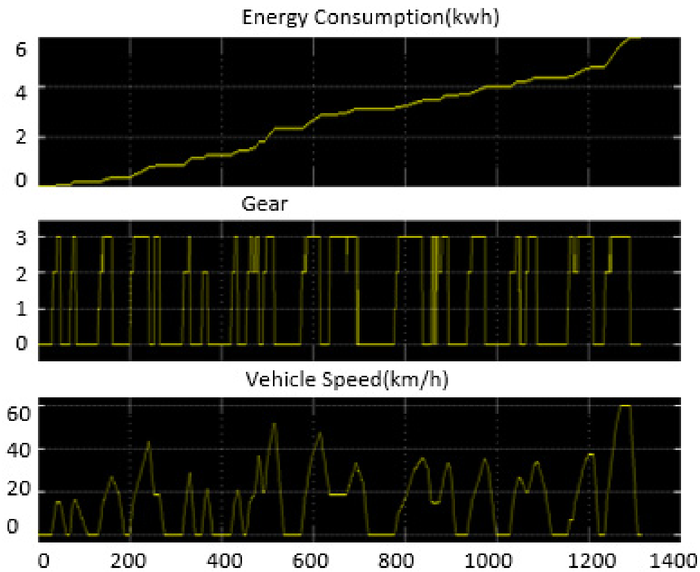

Figure. 8. Simulation results of AMT vehicle (Based on the shift schedule of cyclic operation mode)

The simulation results can be seen in Figure 8, the energy consumption when the vehicle drives 5.8 kilometers is 5.8243kWh. which means the energy consumption when the vehicle drives 100 kilometers is 100.419kWh.

2.5. Results & Conclusions

As clearly shown in Table 3, the energy consumption of AMT pure electric bus which based on the intelligent economic shift schedule of cyclic operation mode is the lowest, compared with the direct-drive bus, the energy consumption reduces by about 21%. Traditional AMT pure electric bus energy consumption is moderate, compared with the direct-drive bus, the energy consumption reduces by about 4%. The simulation results demonstrate the necessity of AMT on the pure electric bus, furthermore, the optimization of the shift schedule of AMT can effectively reduce the energy consumption of pure electric bus.

Table 3 Comparison of economic simulation results

Vehicle type	Direct drive	AMT(Traditional)	AMT(Intelligent)
Energy consumption (kWh/Cycle)	7.4185	7.1208	5.8243
Energy consumption (kWh/100km)	127.905	122.772	100.419
Energy saving rate (refer to the direct-drive vehicle)	/	4.013%	21.489%

References

[1] Mehrdad Ehsani, Yimin Gao, Sebastien E. Gay, Ali Emadi. Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design. 2nd ed. China Machine Press; 2010

[2] Menahem Anderman, The challenge to fulfill electrical power requirements of advanced vehicles, J POWER SOURCES, 127 (2004) 2-7

[3] D.V. Ngo, T. Hofman, M. Steinbuch, A. Serrarens, L. Merkx. Improvement of Fuel Economy in Power-Shift Automated Manual Transmission through Shift Strategy Optimization – An Experimental Study. Vehicle Power and Propulsion Conference (VPPC), 2010 IEEE

Wenwei Wang

received the B.S. degree in vehicle engineering from Shandong University of Technology, China, in 2001.M.S. and Ph.D. degree in the mechanical engineering from Beijing Institute of Technology, China, in 2007. Currently, he is an associate professor of Mechanical Engineering , Beijing Institute of Technology.